2019

THE EFFECTS OF A MODIFIED FIFA 11+ WARM-UP PROTOCOL ON FITNESS VARIABLES IN MIDDLE SCHOOL STUDENTS

McKenna S. Neeb
University of Vermont

THE EFFECTS OF A MODIFIED FIFA 11+ WARM-UP PROTOCOL ON FITNESS VARIABLES IN MIDDLE SCHOOL STUDENTS

McKenna Neeb
Department of Rehabilitation and Movement Science
College of Nursing and Health Sciences
May 2019

Thesis Advisor: Dr. Timothy Tourville, Department of Rehabilitation and Movement Science
Thesis Committee: Dr. Timothy Tourville, Dr. Susan Kasser, Rebecca Choquette

ABSTRACT

Introduction: Lower extremity injuries, specifically anterior cruciate ligament (ACL) injuries are prevalent in adolescent sports. The FIFA 11+ injury-prevention program has been shown to decrease lower extremity injuries in several sports settings. There is limited literature regarding the effects of the FIFA 11+ on fitness variables, especially among middle school students. The purpose of this study was to retrospectively evaluate if a modified FIFA 11+ warm-up protocol has any effect on cardiovascular endurance, muscular endurance, and flexibility at two Vermont middle schools with different physical education class schedules.

Materials and Methods: Outcome data was obtained from the FitnessGram assessment, which is utilized by all Vermont middle schools to track trends in youth fitness levels. The effects of the modified warm-up protocol on cardiovascular endurance (PACER test), muscular endurance (curl-up test), and flexibility (sit-and-reach) at Williston Central School (WCS) were compared to age-matched non-intervention year FitnessGram data at WCS and to intervention year FitnessGram data at Shelburne Community School (SCS).

Results: Statistical analysis for WCS comparing data from the non-intervention and intervention years demonstrated a significant decrease in PACER score ($p < 0.001$), a non-significant decrease in curl-up ($p = 0.207$), and a non-significant increase in sit-and-reach scores ($p = 0.033$) during the year the warm-up protocol intervention was implemented compared to the non-intervention year. The differences in pre- to post-test scores in the intervention year demonstrated a significant decrease in PACER score ($p < 0.001$), a significant increase in curl-up ($p = 0.030$), and a significant increase in sit-and-reach scores ($p < 0.001$). Throughout the intervention year at SCS, PACER and sit-and-reach scores decreased ($p = 0.18$ and 0.31, respectively) and curl-ups increased ($p = 0.96$), although these changes were not statistically significant. The declines in PACER score were significant and larger in WCS compared to SCS.

Discussion: The results of this study indicate that utilization of a prolonged injury-prevention warm-up program in lieu of organized physical education activities traditionally completed during physical education classes at these middle schools may have a deleterious effect on some fitness-related outcomes. It is important to note that this is a small, retrospective investigation and is hypothesis-generating; however, a larger-scale randomized controlled trial should be performed to validate these findings. This information may be used to alter the modified FIFA 11+ warm-up protocol to be effective in both injury prevention and improving fitness among middle schoolers.

Acknowledgements

I would like to thank my advisor, Dr. Timothy Tourville, for his support and guidance throughout the course of this project. I would also like to thank Rebecca Choquette and Dr. Susan Kasser for their guidance and being part of my thesis defense committee. Special thanks to Andy Borah and Mickey Krug for implementing the protocol and helping with the paper. Thank you to Pamela Vacek for her help with the statistics and data analysis for this project.

Table of Contents/List of Figures

Chapter One: Introduction

It is no secret that the prevalence of obesity in the US is increasing in children. In fact, according to the American Heart Association, about 1/6 of children and adolescents between the ages of 6 and 19 are considered obese[1]. Obesity is linked to several other negative health consequences including metabolic syndrome. Even obese preschoolers show some biomarkers associated with cardiovascular risk[1]. Since there is a significant positive relationship between lack of physical activity and obesity, intervening and introducing physical activity would be beneficial and thus help with these disease risks[2].

Physical activity can lower the risk of cardiovascular disease, high blood pressure, diabetes, and some cancers[1]. It has been found that children complete 20-40% of their physical activity in school[3]. Since such a significant amount is completed in school, it is essential that these minutes are used effectively. The national average time of physical education class is 140 minutes, but it has been noted that a large portion of this time is considered to be sedentary activity. One study showed that up to 68.1% of physical education class can be considered sedentary while only 8.6% of the activity was moderate to vigorous[3]. Since the physical activity level of children significantly drops between the ages of 9 and 15, it is important that children reach activity recommendations. It is recommended that children get at least 60 minutes of moderate to vigorous activity daily[1]. Since physical education class can cover a large percentage of this time, it is important that activity occurs.

Children may begin physical activity to help improve their health, but this comes with risk of injury. One trend in the literature is that a high proportion of knee injuries occur in obese athletes[4]. In particular, knee injuries, specifically injury to the anterior cruciate ligament (ACL), are most common in females[5-8]. A study examining ACL injuries in U.S. high school

athletics found that 76.6% of these ACL injuries result in surgery[9]. About the same percentage of injuries resulted from contact and non-contact incidences (42.8% and 37.9%, respectively), and prevention efforts could help lower injury rate[9].

ACL injury has been linked to the progression of osteoarthritis. In fact, most people who tear their ACL are younger than 30 and when they do so, the rupture ages the knee by 30 years. This means that cartilage has eroded, causing effects such as pain and functional limitation[10]. In addition, it has been found that ruptures in the knee lead to a decrease in activity level[11]. Being able to exercise safely is important in reducing the likelihood of injury and reducing the risk of negative health consequences.

The rate of ACL injuries and health consequences such as osteoarthritis can be lowered with an implementation of a pre-practice and pre-competition warm-up protocol. There are numerous methods of injury prevention available for athletes and for the general population. Some of these include neuromuscular, plyometric, and sport-specific strategies, as well as stretching. One protocol used in a pre-participation warm-up for athletics, namely soccer, is the FIFA 11+. It is a twenty-minute warm-up program consisting of exercises such as running and jumping[12, 13]. Its effectiveness has been studied in different populations, ranging from youth to elite soccer players, as well as athletes of other sports[13-15]. The program was first studied in the context of ACL injuries in females, as that specific injury occurs in females more than males by anywhere from two to eight times[5]. The program has also been modified for younger ages and is known as the FIFA 11+ For Kids. The goals of that program include improving coordination and balance, strengthening the leg and core muscles, and optimizing falling techniques[16]. While there is no lack of literature regarding the effectiveness of the FIFA 11+

for injury prevention, there is limited information in the literature regarding the effects of the program on fitness variables.

It has been found that middle school athletes, specifically females, may show similar injury patterns to high school athletes[17]. To avoid injury, it is valuable to teach proper motor patterns at a young age, allowing students to properly move their body, avoid injury, and be able to continue to exercise while combating obesity. Additionally, it would be valuable to see if teaching these motor patterns in a fitness warm-up also increases performance in fitness-related tests. One way to analyze the effect on fitness is by implementing a protocol such as the FIFA 11+, and it is important that it be implemented early in the developmental process of the athletes[18]. By implementing a warm-up protocol similar to the FIFA 11+, the effects of the program on adolescents' fitness variables, shown through performance in the fitness testing, can be analyzed.

One method used for evaluating fitness of adolescents is called the FitnessGram. This nationally recognized test uses standards to evaluate the physical fitness levels of the children as well as the physical education program[19, 20]. Specifically, it examines six areas of health-related fitness: aerobic capacity, body mass index, abdominal strength and endurance, trunk extensor strength and flexibility, upper body strength and endurance, and flexibility[21].

Vermont is one state that completes the FitnessGram assessment in schools. There is limited literature regarding this topic in adolescents, and the populations of students in Williston Central School and Shelburne Community School, two middle schools in Vermont, have not been investigated. The students in each school complete the FitnessGram testing once in the fall and once in the spring. Using FitnessGram results from a typical non-intervention year and an

intervention year at both schools can provide insight regarding the effectiveness of the modified FIFA 11+ warm-up protocol on fitness variables.

Chapter 2: Literature Review

Obesity Trends

The prevalence of obesity in the US is increasing in adults as well as in children[22-25]. These growth curves are similar across sexes until age 9. From there, percent body fat continues to increase for women through adolescence and reaches a median of 27.8% at age 18, but is at its highest in males at 11 years and reaches a median of 17.0% at age 18[22]. Between the 2007-2008 and 2015-2016 years, obesity in youth (ages 2-19) increased from 16.8% to 18.5%[24]. The trend of obesity continues into adulthood. In 2009-2010, the prevalence was 35.5% in adult men and 35.8% in adult women in the US[23]. Based on a projection using national survey data between the 1970s and 2004, the prevalence of children classified as overweight will almost double by 2030, and 86.3% of adults will be overweight or obese and 51.1% obese[25].

Significant predictors of the prevalence of obesity are socioeconomic status, school enrollment, age group, and the prevalence of insufficiently physically active people[2, 26]. In fact, in the US, over half of the population does not meet the minimum recommendation for physical activity[2]. Vermont ranks higher than 44 other US states, but 25% of adults are obese, which if more than double the number in 1990. In addition, there is a 26% obesity rate in adolescents in high school or younger[27]. To combat these rates, in schools across the world, some obesity prevention programs have been implemented, but have been determined to be only mildly effective in reducing the BMI of the children[28].

Injury Rates

Participating in physical activity comes with the risk of injury. Specifically, in the US, of the approximately 30-45 million school-aged children who participate in sports, there are nearly

4 million sport-related injuries annually[29, 30]. One common injury is an anterior cruciate ligament (ACL) tear, which has been shown to be more prevalent in women as compared to men[5-8]. In fact, females may be two to eight times more likely to tear their ACL, and the female to male tear ratio could be as high as 9:1[5, 7]. Sports with high ACL tears include basketball, soccer, lacrosse, and alpine skiing, and when comparing between sexes, females were about three times more likely to sustain an ACL tear in soccer and basketball as opposed to men[7]. These are examples of cutting and landing sports, a category of sport in which females have a 4-6 times greater incidence of ACL tears compared to men[6]. Annually, the incidence in females peaks between ages 14-18, in adolescent years, and this highlights the importance of prevention efforts starting before this age[6, 31]. Implementing an injury prevention protocol may be helpful in reducing these injury rates[5, 6, 8, 13-15, 29, 32-39]. In addition, certain injury prevention protocols may have the added benefit of increasing fitness levels[39-44].

Injuries are prevalent in children in middle school in both practices and in games. One study evaluating multiple sports compared male and female athletes participating in middle school sports and found that, overall, football had the highest injury rate[45]. Of all the injuries reported, 19.1% were tendinitis. When comparing sports played by both males and females, girls had a higher injury rate for all injuries and for time-loss injuries. Females also showed a higher injury rate in practices as compared to games while males showed no significant difference in injury rates of practices and games[45].

Overall, middle schoolers experience less frequent and less severe injuries than older athletes in high school and college[45]. Several studies used High School Reporting Information Online (RIO) to examine injury rate in high school and college students[4, 9, 46-48]. When analyzing injury recurrence, it was found that a small amount (10.5%) or all injuries were

recurrent, but these injuries more frequently resulted in over three weeks of time loss, the same amount of time loss resulting from overuse injuries in collegiate athletes[46, 49]. Injury rates from practice and from competition were also compared. In one study, ACL injury rate was (seven times) higher in competition than in practice, a trend similar to that found in a study looking at lower extremity injury rate[9, 47]. When examining sex-comparable sports, girls had a higher ACL injury rate than boys and a higher lower extremity injury rate in most sports[9, 47]. Lower extremity injuries were the most commonly injury site in high school and collegiate athletes and fatigue may be a factor[47, 49, 50]. Another factor that may relate to lower extremity injuries is BMI. Using weight and height measured by a certified athletic trainer, BMI was calculated and used to categorize high school athletes into underweight ($\leq 15^{th}$ percentile), normal weight (15^{th}-85^{th} percentile), overweight (85^{th}-95^{th} percentile), obese ($\geq 95^{th}$ percentile)[4]. It was found that approximately 2/3 of injuries were in the group of athletes of normal weight, but a higher proportion of knee injuries occurred in the group of obese athletes. A larger proportion of fractures occurred in the group of underweight individuals compared to the group of individuals of normal BMI[4]. It may be logical to incorporate BMI-specific interventions, and interventions targeting overuse and ACL injury[4, 9, 48].

Osteoarthritis

The prevalence of knee osteoarthritis after ACL injuries is estimated to be anywhere between 10% and 90% at 10-20 years post-injury[10, 51, 52]. Affecting up to 15% of the population, osteoarthritis is regarded as a leading cause of disability and a majority of people with osteoarthritis have sustained a previous injury to the knee[52, 53]. Specifically, the lifetime risk for knee osteoarthritis is about 40% in men and 47% in women[52]. Osteoarthritis develops

when there are mechanical issues, specifically when there are increased or altered joint loads[53]. In young adults, a previous injury to the knee usually results in osteoarthritis[53]. With that being said, there are several notable risk factors including joint injury, obesity, aging, sex, genetics, race/ethnicity, joint alignment, and more[52, 53]**.** These risk factors cause muscular deconditioning, increasing the loads on joints and increasing the progression of osteoarthritis[53]. As osteoarthritis progresses, symptoms including pain occur, leading to functional limitations and a decreased quality of life[10]. The long-term symptoms and function in people with osteoarthritis and knee injury can be evaluated with a self-administered score, The Knee Injury and Osteoarthritis Outcome Score (KOOS). It includes the subscales of pain, other symptoms, function in daily living, function in sport and recreation, and knee-related quality of life[54].

Surgery is often an option with an ACL injury, and, although it helps with stabilization, the reconstruction does not reduce osteoarthritis risk[10, 11, 53]. A follow-up for people who underwent surgery for ACL or MCL ruptures showed that patients younger than at the time of the trauma had osteoarthritis of a slight to moderate degree in 58% of patients and 87% of older patients at the time of the trauma had osteoarthritis[11]. These results are similar to that of a review stating that a follow-up of young athletes with meniscus surgery showed that over 50% had knee osteoarthritis[51, 55]. One way to help combat the progression of osteoarthritis post-ACL injury is to monitor gait[53, 56, 57].The degeneration of cartilage following injury may change the loading on the cartilage, potentially causing some new areas to be loaded or experience altered levels of loading[56, 57]. Mature cartilage likely will not adapt to this stress, potentially causing cartilage degeneration and the development of osteoarthritis following ACL injury[56]. When compared to a healthy knee, the knee with ACL injury had a higher rate of

cartilage loss due to the rotational change from the injury[57]. Restoring proper gait could perhaps slow the development and progression of osteoarthritis because the cartilage would be loaded correctly. Maintaining body weight and engaging in regular exercise may also prevent osteoarthritis progression in the young adult population[53].

Injury Prevention Methods

There are several injury prevention methods in the literature, including programs focusing on proprioception, balance, neuromuscular effects, plyometric training, sport-specific training, and stretching. The effects of these interventions alone and combined with one another have been studied in the context of injury prevention.

Stretching

One popular strategy that may be used to decrease injury risk or to enhance athletic performance is stretching. This can be done as a pre-participation or as a post-participation method. If completed before an athletic event, the stretching is used with range of motion in mind. If sufficient range of motion can be achieved, muscle stiffness can be decreased, and muscle compliance can be increased, allowing the activity to be performed with a decreased risk of injury[58]. There are different types of stretching, including static, dynamic, passive, and active. No matter the type, the goal is to affect both injury risk and athletic performance[58].

One population that has been used for studies regarding effectiveness of stretching in injury prevention is army recruits or trainees[32, 33, 59]. Although each study examined the effects of static stretching on instance of injuries, the results of the studies were mixed[32, 33, 59]. Different combinations of stretches and time stretching were used. Some studies found that

stretching was beneficial in relation to number of instances of injuries[33]. In one study, two different companies going through basic training were used; the control company went through normal basic training while the intervention group did the same, but added three sessions per day of hamstring stretching. Both companies had hamstring flexibility measured before the training began[33]. For thirteen weeks, the sessions were hamstring stretching only, with five sets of thirty-second stretches in each leg. With statistical significance, hamstring flexibility increased and number of injuries decreased in the intervention group compared to the control group. In this case, the stretching protocol was reduced the overuse injury in lower extremities[33].

On the other hand, these results are not the case in other studies[32, 59]. A study done on Japan ground defense force military recruits used a protocol for twelve weeks of four upper body, seven lower body, and seven trunk static stretches. The control group did not stretch, and the intervention group stretched before and after training for a twenty-minute session. The intervention group has a statistically significantly lower number of muscle-related injuries as compared to the control, while the bone and joint injuries were not prevented[32]. While these studies show that static stretching may be beneficial, others do not[59]. For example, a protocol of stretching each of six major lower-limb muscles for a single session per day for the duration of twelve weeks was used to assess number of injuries. Each static stretch was held for twenty seconds, and when compared to the control group of army recruits who did not stretch before the physical training sessions, there was no significant effect of the static stretching on the number of injuries in the army recruits of the study[59].

Other studies combine stretching with a warm-up. The thought behind adding a warm-up is that there could be several potential added benefits including an increased speed and force of muscle contractions, increased speed of nerve transmissions, and increased blood flow to the

tissues in use[37]. These hypothesized physiological benefits may help reduce risk of injury. For example, a faster neural transmission could possibly help an individual avoid injuries by improving the individual's reaction time[37]. Other findings have found that if stretching is performed as a pre-participation activity, the ability to generate maximal force is reduced[58]. In this case, stretching would be detrimental to an individual's performance. This conclusion is not supported by some other literature[60]. In a study of Portuguese children aged 9-12, the association of flexibility and motor competence was examined through using a body coordination test (Körperkoordination Test für Kinder) consisting of balance, jumping laterally, hopping on one leg over an obstacle, and shifting platforms. The flexibility tests (sit-and-reach and trunk lift) were found to be significant predictors of motor competence, perhaps suggesting that the development of flexibility in combination with other fitness variables may be integral in developing motor competence[60]. Overall, the literature is inconclusive regarding whether flexibility is beneficial in reducing injury risk and fitness test performance[32, 33, 37, 58-60].

Sport-Specific and Neuromuscular Training

Warm-up protocols including neuromuscular training are widely studied, indicating it is a reliable method to reducing injury rates among several populations. These injuries include those to the hamstring muscle and to the knees[8, 29, 34, 35].

Including sport-specific training can decrease hamstring injury and competition days missed[34]. The implementation of an intervention program including stretching when fatigued, sports-specific training drills, and high-intensity anaerobic interval training significantly decreased the hamstring injuries in an Australian Rules football team over the course of four seasons. Combining several aspects of training to create an intervention with neuromuscular

effects is advantageous and can be seen in other training protocols such as neuromuscular interventions[8, 29, 35].

As for the relationship between neuromuscular training and injury, both middle schoolers and high schoolers have been studied[8, 29]. At the school-age level, in one study, the females at the middle schools and high schools in a school district were divided into different intervention groups: the CORE intervention group doing exercises focused on trunk and the lower extremity and the SHAM intervention group doing resisted running with elastic bands[29]. When compared to the SHAM intervention, the neuromuscular CORE group had a reduced injury incidence rate, reporting a rate of 5.34 injuries/1000 athlete exposure compared to the 8.54 injuries/1000 athlete exposures from the SHAM group. When specified by injury, the CORE intervention reduced knee injuries at the middle school level more than the SHAM intervention[29]. In another study, after incorporating a 6-week preseason neuromuscular training program to the intervention group comprised of 43 sports teams from 12 high schools, the incidence of knee injuries can be analyzed[8]. The untrained female athletes were 3.6 times more likely to sustain a knee injury than the trained female athletes and the difference in the noncontact injury rates between the groups was significant[8].

These effects are studied in older individuals at a higher level of sport, specifically the high school and collegiate level. In a study of women ages 14-18, the effects of a traditional warm-up were compared to a sports-specific training intervention. This intervention used a neuromuscular and proprioceptive training program including education, strengthening, plyometrics, and sport-specific drills as a warm-up protocol[5]. In the first year of the intervention, there was an 88% decrease in ACL injury in the intervention subjects as compared

to the control group and this trend continued into the second year, where there was a 74% reduction in ACL tears in the intervention group compared to the control group[5].

These findings extend to the collegiate level. One study examined Division I women's soccer teams; the intervention group completed a neuromuscular and proprioceptive training program three times per week[35]. The study concluded that this program centered on neuromuscular control seemed to have reduced the risk of anterior cruciate ligament injuries in this sample. The overall ACL injury rate was 1.7 times less in the intervention group overall and 3.3 times less in the intervention group for non-contact injuries[35].

It is also possible to compare incidence of knee injury in males and females. Three groups, female athletes trained in a neuromuscular program, untrained females, and untrained males. After six weeks, there was not a significantly different incidence rate of knee injury in the trained females compared to the males[8]. Analyzing this injury rate across sexes can help highlight the female vulnerability to ACL injury.

FIFA 11+

One warm-up protocol with the aim of reducing injuries in males and females ages fourteen and older, more specifically soccer athletes, is the FIFA 11+[13-15, 61]. This program was developed by the FIFA Medical Assessment and Research Centre (F-MARC) and consists of exercises using running, strength, balance, and jumping[12, 13]. The program combines stretching in the running segment, as the running is completed at a low velocity and includes active stretching. In total, it is a twenty-minute program: one component uses skills such as cutting and change of direction; the strength, plyometric, and balance component emphasizes core strength, control during the eccentric portion of a movement, and proprioception; lastly, a

final component with running exercises is completed[14]. Each of the exercises has varying levels of difficulty, so the athlete can progress or regress as necessary[13, 44]. The main focus when introducing this protocol to athletes is to improve the body awareness, neuromuscular control, and muscular strength by completing these exercises[14, 15, 36]. Figure 1 portrays the protocol divided into the three parts.

FIFA 11+ For Kids

FIFA 11+ For Kids is a modification of the FIFA 11+ program developed for children between the ages of 7 and 13. It focuses on improving coordination and balance, strengthening the leg and core muscles, and optimizing falling techniques[16]. It is composed of seven exercises. Like the FIFA 11+, the exercises are to be performed at the beginning of each training session and will take a total of 15-20 minutes to complete. There are five levels per exercise, progressing in difficulty. The child is permitted to move to the next level if he or she can correctly perform an exercise on multiple occasions with little or no corrections[16]. The exercises consist of: “Alertness” running game, skating jumps, single-leg stance, press-ups, single-leg jumps, Spiderman, and sideways roll. Each exercise and its respective progressions are outlined in Figure 2.

There is limited literature surrounding the FIFA 11+ For Kids and its effectiveness, but studies on youth soccer have indicated that the program may be beneficial for increasing performance and minimizing injury[62, 63]. In one study, twelve soccer teams were divided at the team-level into intervention and control teams, with the intervention group performing the FIFA 11+ For Kids Protocol two times per week for a total of ten weeks and the control group performing a standard warm-up lasting the same amount of time[62]. Pre- and post-tests for

multiple tests were used to assess the effectiveness and showed likely beneficial effects in a balance test (right side) and agility run, possibly beneficial effects in the balance test (left side) and jumping, and likely little effects for single-leg balance and for a 20-meter sprint[62]. The other study divided the players within each team, with the intervention group completing the program two times per week for a total of four weeks and the control group completing a normal warm-up routine. Thirteen physical performance measures were taken, and the data showed that the intervention group performed better in dynamic postural control, vertical jump height, agility run, and horizontal jump while the control group performed better in the 20-meter sprint and the wall volley test[63]. In both scenarios, implementation of the FIFA 11+ For Kids was able to at least slightly enhance performance in the physical performance tests[62, 63]. With the increased performance in these domains, it is logical to conclude that the soccer injuries may be reduced in children who regularly complete the FIFA 11+ For Kids protocol[62].

Effectiveness of FIFA 11+ in Injury Prevention

Initial studies of the FIFA 11+ analyzed the effectiveness in injury prevention regarding female soccer athletes knee injuries, specifically of ACL[5, 8, 35]. More currently, the research has extended to the population of male soccer players and to athletes of various levels and ages. For example, a population of African male youth soccer players was studied[15]. Overall, there were significantly lower injury rates in the intervention group that completed the FIFA 11+ protocol compared to the control group. Specifically, the FIFA 11+ reduced the overall injury rate by 41% and the lower extremity injury rate by 48% at a significant level[15].

Youth female soccer players were also researched to examine the effectiveness of the FIFA 11+ in reducing the risk of injury. Once again, the participants were divided into control

and intervention groups, with the intervention group completing the warm-up program before every training session through the duration of the season (the program was also completed as a warm-up for each game)[13]. The control group did not perform a structured warm-up protocol. The results were divided into different outcomes, with the intervention group having a significantly lower risk of injuries when the data was sorted by overall, overuse, and severe injuries[13]. Unlike the aforementioned study on male youth soccer[15], the calculated reduction in injuries to the lower extremity did not reach a level of significance. At the youth level, these studies indicate that the FIFA 11+ warm-up protocol is effective in reducing injuries in soccer players.

Research regarding the effectiveness of FIFA 11+ has also been completed at the Division I and II collegiate levels. At the collegiate level, male Division I and II teams were looked at, dividing each into control and intervention groups, respectively. For each division, there were a significantly higher number of game injuries per team in the control group compared to the intervention group[14]. In both divisions, incidence of injury among the control group was significantly higher than that of the intervention group. Other examined variables were age and position, showing no significant difference in injury risk in the different ages or position[14]. This supports the idea that the FIFA 11+ is effective in multiple age groups.

Fitness Testing

Starting in the 1950s, fitness testing has evolved through the years, first evaluating motor fitness and more recently evaluating health-related physical fitness[20]. There is a strong relationship between health outcomes and fitness in young people, so it is important to do this testing[20, 64]. It is common to measure factors such as cardiorespiratory fitness, body

composition, flexibility, and muscular strength and endurance, and the FitnessGram testing protocol does just that[20, 21].

FitnessGram

The FitnessGram utilizes a variety of fitness-based tests to classify the student based upon his or her risk of metabolic syndrome. It is designed to measure aerobic capacity, body mass index, abdominal strength and endurance, trunk extensor strength and flexibility, upper body strength and endurance, and flexibility[21]. To measure cardiovascular fitness, tests such as The Progressive Aerobic Cardiovascular Endurance Run (PACER) test or a one-mile run or walk is used. An equation can be applied to any one of these aerobic tests to convert them to VO_{2max} scores, representing aerobic capacity. The other tests measure muscular strength and endurance and flexibility and consist of a push-up, curl-up, trunk lift, and sit-and-reach test.

The results of the tests classify the student into categories based on risk of metabolic syndrome. A person has metabolic syndrome when a cluster of symptoms that increase their risk of other complications such as cardiovascular disease and diabetes is present. If a person is in the healthy fitness zone, "HFZ," he or she is considered to have very low risk of metabolic syndrome and a good fitness level. "NI-HR" means that the student needs improvement and 95% of children without metabolic syndrome have fitness levels above this. At the lower end, "NI" means that they have an aerobic capacity that could indicate moderate risk of metabolic syndrome[21]. Although all students are classified by these criteria, the standards are age- and sex-specific. Overall, the data of the FitnessGram tests can help identify who could benefit most from an improved fitness level, which is consistent with the goals of fitness testing in general[20, 21].

Sex Differences in FitnessGram Results

Sex differences in FitnessGram results has been studied, specifically focusing on cardiovascular and body composition values[19, 65, 66]. In Georgia, growth curve models were used to take the percentage of students reaching the HFZ and estimate the annual changes[65]. At the elementary school age, both sexes significantly improved the proportion in the HFZ over time. As for body composition, the boys had significant increases in the proportion reaching the HFZ. The trend was not found to be the same among middle school and high school students[65]. The same variables were examined in St. Louis, Missouri, and it was found that sex was a significant predictor of fitness category achievement in the FitnessGram aerobic capacity test and in body percent fat[19]. For both of these measures, a higher proportion of girls failed to meet the HFZ category. Another statistic was that, according to the FitnessGram classifications, >66% of the students (both sexes) had risk factors for metabolic syndrome[19]. It is very important to note this, as the data can help schools create new approaches to improve fitness and reduce risk for metabolic syndrome among students[20].

A significantly larger sample was used to examine cardiorespiratory endurance across sexes in 50 countries. Data from 1,142,026 people ages 9-17 was used to create normative values for 20m shuttle laps and for VO_{2peak} value[66]. There were some sex-related differences: regardless of the age group, boys outperformed girls and a higher proportion of boys had a healthy cardiorespiratory endurance value than girls[66]. These differences increased with age. There was a finding regarding cardiorespiratory endurance that did not concern sex; the prevalence of healthy cardiorespiratory endurance decreased with age[66]. These findings are important because they help capture the problem and changes can be implemented from there.

Reliability and Validity of FitnessGram Testing

Reliability of the FitnessGram can be assessed by first looking at the individual testing components[67-70]. Two studies looked at the reliability and validity of the sit-and-reach testing component[67, 69]. They had very similar findings: the back-saver sit-and-reach test was a better measure for hamstring flexibility than lower back flexibility, but is not a good measure for either. In the study on elementary school children, the test was deemed unacceptable to moderate in validity for hamstring flexibility and extremely low in validity for lower back flexibility[67]. These findings were the same in middle school girls and boys; the validity of the back-saver sit-and-reach test as a measure for hamstring flexibility was moderate and the validity for lower back flexibility was low[69].

Other tests were also examined, namely the trunk lift and the mile run/walk and PACER[68, 70]. The trunk lift test was found to be highly reliable in high school boys and girls, and it is suggested that the relationship between low back pain and trunk lift scores be investigated[68]. When college-aged participants completed the trunk lift test twice per day for 4 days, the reliability was found to be very high[71]. As for the mile run/walk test and the PACER test, there were sex differences in these 4th and 5th graders. There was a similar percentage of boys who passed the PACER and the mile run/walk test, but the percent of girls who passed the PACER test was much higher than the percent of girls who passed the run/walk test[70].

Relationship of FIFA 11+ and Fitness Variables

There is an abundance of literature regarding FIFA 11+'s effects on injury prevention, but there is limited information about its effectiveness on fitness. With that being said, some findings include increased strength, vertical jump measures, agility, sports skill, stabilization,

core stability, and aerobic performance[39-42]. To measure effectiveness, some studies compared the FIFA 11+ to the HarmoKnee program[40, 41]. In one study on young male professional soccer players, the FIFA 11+ was effective in increasing quadriceps and hamstrings strength at 30º, 60º, and 90º of knee flexion, while a comparable program, HarmoKnee, only showed improvements in quadriceps strength[40]. In another study of professional soccer players, the group using the HarmoKnee program experienced an increase in soccer skill, but the FIFA 11+ was overall more effective, as it increased their vertical jump scores, agility, and soccer skill[41]. As for effects on stabilization, male amateur soccer players were found to have a faster time-to-stabilization and more core stability after using the FIFA 11+ program three times per week for nine weeks[42]. Other outcomes that have been analyzed include muscle structure and activation[72, 73]. Findings may suggest an alteration in neuromuscular control following the intervention and activation of the hip abductor muscles and abdominal rectus during the FIFA 11+ intervention[72, 73].

Recent Related Findings

In Texas, students in sixth grade completed a "FitnessGram Friday" once per week with the goal of improving fitness, specifically aerobic and muscular endurance. There were significant improvements in push-up scores, trunk lift scores, and mile run times across sexes[74]. In addition, the percentage of students achieving "Healthy Fitness Zone (HFZ)" classification greatly increased across sexes (3% to 22% after intervention in males and 4.5% to 20% after intervention in females)[74].

There is one study that is closely related to the aim of this study, analyzing the effects of a neuromuscular training program on fitness variables. Students, ages 11-15, in physical

education class either completed a 12-week neuromuscular training program or a standard warm-up including running and stretching[39]. The neuromuscular training program included aerobic, strength, balance, and agility components. Results showed that the intervention program was more effective than the control in reducing injury rates, reducing waist circumference, and increasing aerobic fitness. At the time of publication, this study was the first pilot randomized controlled trial studying the efficacy of an injury prevention program in junior high school students[39]. The training program closely models the warm-up program that was implemented in this study at WCS and SCS in Vermont.

Review of Similar Study

A recent study from Richmond et al examined the effects of a neuromuscular training program on sport injury risk and health outcomes[39]. Two middle schools of equivalent socioeconomic areas in Calgary, Alberta were randomly assigned to either the intervention group or the control group for a 12-week period. These schools were composed of students in grades 7, 8, and 9. Students were excluded from the study if they had a medical condition and/or history of musculoskeletal disorders that would prevent full participation in physical education classes. In Alberta, the physical education classes complete 150 minutes per week of physical education class, divided in any way. These schools completed this by having physical education class two or three times per week.

Primarily, the study aimed to analyze the effects of the neuromuscular training on all sport injury. As for secondary outcomes, the study examined lower extremity injury, injury resulting in time loss, ankle and knee sprain injury, changes in waist circumference, and changes in aerobic fitness. These variables were collected in each school by trained certified exercise

physiologists or physiotherapists, and they were blind regarding if the students were in the control or intervention group. Waist circumference was measured to the nearest 0.5cm, height to the nearest 0.5cm, weight to the nearest 0.1kg, and aerobic capacity was indirectly measured with a multistage shuttle run test, the Leger 20m shuttle run test[75].

Both the intervention and the control groups completed a 15-minute warm-up prior to physical education class. The students in the intervention group completed a progressive, continuous neuromuscular training aerobic session and a 5-min training component focusing on balance as well as core and lower extremity strength. The exercises of the neuromuscular training sessions were chosen because they were able to produce at least 75% of max heart rate (as measured weekly by a heart rate monitor), an intensity that has been demonstrated in the past to increase cardiorespiratory fitness and decrease body fat in adolescents. The warm-up of the control group consisted of a 10-minute low-intensity jog around the gym and a 5-minute session of static and dynamic stretching. In both schools, the physical education teacher taught the warm-ups at the beginning of each physical education class. The teachers learned the respective warm-up from a certified exercise physiologist and physiologist prior to the start of the study. Additionally, the teacher was blinded to components of the exercise program in the other school. All participating students kept a weekly journal documenting leisure time physical activity and weekly sport participation.

Overall, the neuromuscular training was shown to reduce the risk of injuries (all, lower extremity, and time-loss), matching similar studies. Waist circumference increased in both groups, but the increase was significantly less in the intervention school. There was a small change in aerobic fitness overall. The authors of the study expressed that this could be clinically relevant considering the short duration of the study. They noted a couple limitations, too,

specifically that they did not require the students to record their energy intake (something that could explain the body composition results) and they noted that the weekly questionnaires rely on recall, which could be biased.

Chapter 3: Methods

Goals and General Procedure

The goal of the study is to compare fitness assessment scores among middle school students to assess the effects of a modified FIFA 11+ warm-up protocol. The PACER, curl-up, and sit-and-reach scores are used to measure cardiovascular fitness, muscular endurance, and flexibility, respectively. At Williston Central School, the students in the fall 2016-spring 2017 year completed a typical physical education class warm-up, and that same group of students (with only a few exceptions) completed a modified FIFA 11+ warm-up prior to physical education class in their fall 2017-spring 2018 school year. The change in test scores in the fall and spring of the non-intervention year as well as the change of test scores in the fall and spring of the intervention year can be compared to observe if the implementation of the modified warm-up had an effect on the three FitnessGram test variables. The WCS data from the 2014-2015 school year were incorporated because it included students of the same grades. The data from the non-intervention year were comprised of students grades 5-7 and the data from the intervention year were comprised of students grades 6-8 to capture the same group of students. The 2014-2015 data has information from grades 5-8, so the information can be compared to the students of the same grades. The same warm-up protocol was implemented in Shelburne Community School from fall 2017-spring 2018. The FitnessGram data from the fall and spring of that year can be used to assess the fitness changes throughout the intervention year, and the change in test scores from fall to spring in SCS can be compared to the changes in WCS. Overall, the trends in FitnessGram scores can be compared between the two middle schools to assess the effects of a modified FIFA 11+ warm-up protocol on fitness variables in middle school students.

Subject Sample

Students at WCS are divided into five class periods, each a random mix of students with an average of 25 students per class. Class placement is determined by the student's world language schedule at the beginning of the year. Students stay in the same class for the majority of cases except of those of severe injury, etc. WCS is composed of students grades 5-8 and SCS is composed of students grades 6-8. FitnessGram testing is completed twice each year at each school, once in the fall and once in the spring. In the comparison between the non-intervention year and intervention year at WCS, only students with scores in all four tests were used for analysis. At SCS, only students with score in both the fall and the spring tests were used for analysis. All subjects provided written informed consent and IRB approval was obtained for this study.

Procedure

Physical Education Structure. Williston Central School follows the structure of twelve weeks of physical education class on Monday-Friday, twelve weeks of no physical education class, and finish the school year with twelve weeks of physical education class on Monday-Friday. Each class was composed of approximately twenty-five students, and there were five classes per rotation. There were three rotations total. The classes were composed of students from any grade level, as physical education schedule was based on the child's world language class schedule. In the fall, the students spent one week learning the protocol.

At WCS, when the students were in physical education class, they spent about 2.5 weeks completing the intervention prior to class. They would then spend about a week completing FitnessGram testing, and finish with approximately 2.5 weeks completing the intervention before

gym class. One group from the second rotation was chosen to do gymnastics in class. This setup caused the cardio program to be skipped for two weeks and the strength program to be completed on Monday, Wednesday, and Friday prior to FitnessGram testing the second time. The third rotation completed their FitnessGram testing early in the spring due to their scheduled spring break from school. That group of students implemented the protocol for only three days before being tested.

Shelburne Community School followed a physical education structure of two classes per week. The students completed the modified FIFA 11+ warm-up protocol before physical education class, with one class each week being the cardiovascular exercises and the other class being the strength exercises. Each class had approximately twenty students and the classes were composed of students of the same grade level. It took about one total class for the students to learn the implemented warm-up protocol. The FitnessGram assessment was completed in the fall and in the spring.

Past Warm-Up. At WCS, when the students were in a non-intervention year, they would complete their typical warm-up prior to their physical education class. For example, in the fall 2016-spring 2017 year, the students would run one lap around the track (the track is around an athletic field and is a bit longer than 400m) or ten laps around the gym as a cardio warm-up, and this occurred every Monday, Wednesday, and Friday. For a strength warm-up, the students would complete an exercise similar to a star balance excursion test and do some push-ups and squats. The students did not complete this together; instead, they began after they got changed into gym clothes.

At SCS, in the past, students would complete a warm-up before the start of class. If the student did not wear gym clothes to school that day, they would have to change before class.

While those students changed, the others would complete some exercises written on the board: one being cardio, and 1-2 being strength or flexibility. Once everyone was ready for class, the students picked 3 exercises from a list of 10-15 to complete for a dynamic warm-up. Some options included inch worms, butt-kicks, high knees, etc.

Implemented Warm-Up. At WCS, in the fall 2017-spring 2018 year, a modified FIFA 11+ warm-up was implemented. Five classes were needed for a certified athletic trainer to teach the students the warm-up in the first rotation of the implementation. In the first class, the students learned exercises 1-5 of the cardiovascular protocol. In the second class, they learned exercises 1-4 of the strength protocol. They then learned the remainder of the cardiovascular and strength programs on the third and fourth days, respectively. The fifth class was used to review the entirety of both the cardiovascular and the strength protocols. For the second rotation, in the spring of 2018, the students came off of their twelve-week break of physical education class. This time around, the students only required one full class day, a forty-minute block, to review the warm-up protocol.

At SCS, a certified athletic trainer taught the warm-up intervention and was present for most of the implementation for the classes. The physical education teacher was there to assist. It took about a full class total of time to teach the students the protocol.

As for learning the protocol, none of the physical education teachers taught the program. The teaching of the protocol was done by certified athletic trainers from the University of Vermont. The athletic trainers taught the WCS physical education teachers about the program, showing them what should be corrected when the students completed it. During the learning period of the exercises, there was a minimum of three people correcting the students. After the learning period, only the physical education teacher was present during class to correct the

students. There were warm-up charts posted in the gym. The cardiovascular warm-up (Table 1) was posted by the cones and the strength warm-up (Table 2) was posted on the wall that the students face. At both schools, the physical education teacher was present to assist with the warm-up each day.

Cardio Set-Up. On Mondays, Wednesdays, and Fridays, the students completed the cardiovascular protocol of the modified FIFA 11+ protocol prior to the gym activities. At WCS, the gym was set up in order for the length of a basketball court to be used. Five different colored cones were set up, with one at the baseline, foul line, midline, other foul line, and end of the court. At SCS, there were also five cones set up across the gym and the students were in four lanes, usually the same lane each time. Exercises were to be completed at four of these cones. The students jogged to each cone, completed the chosen exercise at each cone, then jogged the full way back.

Cardio Protocol. The cardiovascular exercises were modeled after the FIFA 11+, but some exercises were modified. Table 1 shows the exercises performed in class. For the "Hip In" and "Hip Out" exercises, the students would perform the exercise on the right leg at the first and third cone and on the left leg at the second and fourth cone before jogging back. It is important to note that the "Shuffle Jump" exercise is modified from the "Shoulder Contact" exercise in FIFA 11+. In the modified program, there was no partner contact. Figure 1 outlines the protocol for the FIFA 11+. Another important note is that the "Plant and Cut" from FIFA 11+ was modified to be "Plant and Pause." The pause was used instead, so the student would have to hold the position longer. The students did not have to change direction as quickly with this modification. The other exercises were the same as the FIFA 11+ exercises.

Strength Set-Up. On Tuesdays and Thursdays, the students completed the strength protocol of the modified FIFA 11+ protocol. At WCS, the students lined up down the basketball in three courts while facing the wall. Every student completed the warm-up together. At SCS, the students found a spot on the line or sometimes would stand in a circle to perform the exercises.

Strength Protocol. Similar to the cardiovascular protocol, the strength exercises were modeled after the FIFA 11+, but some exercises were modified. Table 2 shows the exercises performed in class. One difference between the FIFA 11+ and the modified program is with the "Side Bench." In the modified program, the students could either stack their knees or their feet, depending on skill level. The students progressed as they felt comfortable and as form allowed. The time domain was the same: twenty to thirty seconds. For the "Single Leg Balance," the students kept their hands on their hips instead of holding a soccer ball. The modified FIFA 11+ program did *not* complete a hamstrings exercise. This decision was made for several reasons: students may be too young or unable to perform the movement, the gym floor is uncomfortable to directly put their knees on it, and the school policy is to try to avoid the students from touching one another. Instead, the students did a "T-Balance," as noted in Table 2. The T-balance is a single-leg Romanian deadlift with just bodyweight. This was performed after the "Single Leg Balance," so the students would already be warmed up to do another single-leg exercise. This is a different order than the typical FIFA 11+ protocol. For the "Squat to Toe Raise," the students did the repetitions as they could, about ten to fifteen total. Lastly, the modified program added push-ups to the strength warm-up. The students were instructed to complete any variation that is challenging for them, for a total of ten to twenty reps. For example, students could complete their push-ups against the wall, on their knees, or do eccentric push-ups. The other exercises are the same as found in FIFA 11+'s Level 1 category.

Measurements

Testing Procedure. Once the students reached their FitnessGram testing week, the ordering of the tests may have differed, but they were all completed in the week time period. At both schools, the students had the option to repeat a test if they wanted to improve the score or if they were absent on the day of the test. At WCS, each student recorded his or her own score and turned it in to the teacher after class to be inputted into the computer by a teaching assistant. At SCS, each class was split into two groups. One of the groups did an activity or sits on the sideline while the other group does the FitnessGram assessment. The physical education teacher scored all of the students for each fitness assessment. At WCS, the protocol was altered for students who need modifications. At SCS, the students could modify the exercises, but the score would only count for the repetitions of non-modified exercises completed.

PACER. The PACER test measures the aerobic capacity of the student. At WCS, the student must run twenty-meter distances at a certain pace, and the pace becomes faster each minute. If the student makes it across the twenty meters before hearing a beep, they must wait until the beep sounds before starting up again. A triple beep sounded at the end of each minute and signified that the pace was about to increase. At WCS, there was one student counting per each student participating in the test. If the student was close to missing the line or just missed it in the time limit, the counter put one hand up to signify a warning. The counter stayed at one endline the entire time. If another mistake is made, then the student is done with the test. The student then records the number of laps that he or she successfully completed. In the past, the student had to either touch the line, or have one foot over the line. Starting in fall 2018, the students were required to have two feet over the line.

At SCS, the students completed the 15-meter PACER test due to the size of the gym. PACER15 scores can be converted to PACER20 scores to compare the scores and to calculate an aerobic capacity value for the student. Figure 3 shows the conversions. The students were required to have only one foot touch the line for each distance covered. Similar to WCS, the students at SCS were allowed one warning.

Curl-Up. To measure abdominal strength and endurance, the curl-up test is performed. A 3-inch wide piece is used for 5- to 9-year old children, while older students use a 4.5-in wide piece of tape. The student will lie down on a mat with bent knees and feet flat on the floor, aligning their fingertips with the top of the strip of tape. Following the cadence of a CD, the student will curl-up far enough so the fingers pass the other end of the tape. Like the PACER test, each student is allowed two mistakes. Upon the first mistake, the counter taps the student's foot, and upon the second mistake, the test is over. The student is credited for the last successful completed repetition. The student records his or her score at the end of the test.

Sit-and-Reach. To measure flexibility, the students complete the sit-and-reach test as part of the FitnessGram testing procedure. The student removes his or her shoes and sits on the floor with one leg straight and against the measuring box and one leg bent with the foot flat on the ground. The student places one hand on top of the other, with palms facing down. From here, the student reaches as far as flexibility allows. The student performs this test three times for each leg, recording the best score.

Chapter 4: Results

Four variables were analyzed at WCS and SCS: PACER, aerobic capacity, curl-ups, and sit-and-reach (an average of right and left sides).

Williston Central School

Intervention Year. Comparing the pre- to post-tests of intervention year at WCS demonstrated a significant decrease in PACER score ($p < 0.001$), a significant increase in curl-up ($p = 0.030$), and a significant increase in sit-and-reach scores ($p < 0.001$).

Intervention Year Versus Non-Intervention Year. The intervention year had significantly higher pre-test scores in the PACER, curl-up, and sit-and-reach tests. The intervention year had significantly lower post-test scores for PACER, and significantly higher scores for curl-ups and sit-and-reach. The change from pre- to post-test in PACER scores was significantly lower in the intervention year than in the non-intervention year, and the intervention group showed a significant decline from the pre-test ($p < 0.001$) and the non-intervention group showing no significant change. The change from pre- to post-test in curl-ups showed a significant increase in both the intervention and non-intervention years. The increase was larger in the non-intervention year, but this was not a significant difference from the intervention year ($p = 0.207$). As for sit-and-reach, the change from pre- to post-test was greater in the intervention year. The intervention year showed a significant increase and the non-intervention year did not show a change. Comparing the changes from pre- to post-test scores in the intervention and non-intervention years demonstrated a non-significant increase in sit-and-reach scores ($p = 0.033$). The amount of decline in PACER scores and aerobic capacity in the intervention year was significantly related to pre-test score, and the higher pre-test scores showed the largest decline.

For curl-ups, the increase in score from pre- to post-test was inversely related to the pre-test curl-up score, and this relationship did not differ between the intervention and non-intervention years. Results can be seen in Table 3.

Intervention Year Versus Non-Intervention Year in Males and Females. The males scored significantly higher in pre- and post-test scores for PACER, aerobic capacity, and sit-and-reach compared to the females in both the intervention and non-intervention years, but there was no significant difference in curl-up scores. The differences in pre-test scores between the intervention and non-intervention years were similar for males and females except the curl-ups. The curl-ups showed a bigger increase from the non-intervention to intervention year for boys than girls ($p = 0.033$). The differences between the intervention and non-intervention years on post-test scores did not differ significantly between males and females in any measure. Results can be seen in Table 4.

Non-Intervention Year Versus 2014-2015 Data in Grades 5-7. There were no significant differences in pre- or post-test scores. The changes in score from pre- to post- test in PACER and aerobic capacity were greater in 2014-2015 than in the non-intervention year. The changes in score from pre- to post-test in curl-ups and sit-and-reach did not differ between the 2014-2015 school year and the non-intervention year.

Intervention Year Versus 2014-15 Data in Grades 6-8. There were no significant differences in pre-test PACER, aerobic capacity, and curl-up scores. Pre-test sit-and-reach scores were higher in the intervention year. The intervention year had significantly lower post-test scores for PACER and aerobic capacity compared to 2014-2015. The intervention year had higher post-test sit-and-reach scores than in 2014-2015. The curl-up scores did not differ between the two years. The change in score from pre- to post-test in PACER and aerobic

capacity was greater in 2014-2015 than in the intervention year, with 2014-2015 showing a significant increase from pre- to post-test and the intervention year showing significant decreases. The change in score from pre- to post-test for sit-and-reach was significantly greater in the intervention year than in 2014-2015 and the change in curl-up score did not differ between the intervention year and 2014-2015.

Shelburne Community School

Between the two FitnessGram tests, there was a non-significant decline in PACER score ($p = 0.18$), a non-significant increase in curl-up score ($p = 0.96$), and a non-significant decline in sit-and-reach score ($p = 0.31$). These results can be seen in Table 5.

WCS vs. SCS

The changes in PACER score were significant and larger in WCS compared to SCS ($p < 0.001$). The changes in curl-up score between the two schools was not significant ($p = 0.208$). The changes in sit-and-reach score between the two schools was significant ($p < 0.001$). Since SCS had a non-significant decline while WCS had a significant increase in sit-and-reach, there was a significant difference between the pre- and post-test differences between the schools. The pre-tests were lower at SCS for PACER and significantly higher for curl-ups ($p < 0.001$) compared to WCS. The SCS post-tests were significantly higher for curl-ups ($p < 0.001$) and were lower for sit-and-reach compared to WCS. The declines in PACER score were significant and larger in WCS compared to SCS which is partly due to the inverse relationship between pre-test score and size of decline, as SCS had lower pre-test scores. These results can be seen in Table 5.

Chapter 5: Discussion and Conclusions

This study examined the effects of a modified FIFA 11+ warm-up on fitness variables in middle school students at two Vermont middle schools. Overall, there were favorable effects on the curl-up assessment, unfavorable effects on the PACER, and mixed results on the sit-and-reach test. It was consistent across both schools that PACER score, measuring cardiovascular fitness, decreased. Across the intervention years alone, curl-up scores increased in both schools and sit-and-reach scores had mixed results. When comparing the non-intervention to intervention year at WCS, curl-ups decreased and sit-and-reach increased. The schools followed different gym schedules, but the results showed the same trends.

The decline in PACER score may be due to the change in warm-up from a typical year to an intervention year. At WCS, the students previously had to run to and around a large track (>400m) before starting the class activity. If weather did not permit, students ran 10 laps around the gym. Some students raced through the lap to get to the activity. The aerobic exercise in doing this may be more beneficial to cardiovascular fitness than the modified warm-up protocol. This may account for the decreases in PACER scores when comparing the changes in PACER score across the non-intervention and intervention years. Additionally, this may explain why the fittest group (students with higher pre-tests) had the largest declines; they may be the ones sprinting the warm-up lap. It is important to note that the students with the lower pre-test scores also had a decrease in PACER score from pre- to post-test. They may be the students who typically walk the warm-up lap, so it would be reasonable to conclude that the modified warm-up would be beneficial for their cardiovascular fitness, but it was not. It is also important to note that the students had the option to run around the track while the other students were changing for class, but, according to one of the athletic trainers teaching the modified program, only very few would

choose to do so. Adding a running component such as this may be beneficial for the WCS students.

SCS also showed the decline in PACER score from pre- to post-test during the year with the modified warm-up protocol. The warm-up completed at SCS before the intervention year included dynamic movements, more similar to the implemented FIFA 11+ warm-up protocol than what was completed at WCS. This may account for the smaller decline in PACER score compared to WCS. The implemented warm-up still had deleterious effects on cardiovascular fitness.

Between the WCS non-intervention and intervention years, curl-ups decreased significantly, suggesting that the warm-up protocol was not beneficial for abdominal muscular endurance in these students. Throughout the year with the intervention, the curl-ups increased at the two schools, with the increase being significant at WCS. The increase in that year for both schools may be due to including planks in the modified warm-up.

Sit-and-reach scores increased at WCS from the non-intervention year to the intervention year and throughout the intervention year while they non-significantly decreased at SCS. The improvements at WCS may be due to the introduction of flexibility exercises. An exercise specifically of note is the T-balance completed on the strength days. A T-balance is essentially a Romanian deadlift performed using only bodyweight. The student hinges at the hip, thus stretching the hamstrings during the movement. Repetitions of this may improve hamstring flexibility, the type of flexibility that the sit-and-reach test primarily assesses. It is logical for the sit-and-reach scores to improve with the addition of this movement, as flexibility was not addressed in the warm-ups prior.

There are some key differences in the FitnessGram testing administration at WCS and SCS. Both schools follow the published protocol, but each school treats the use of modifications differently. At WCS, the students are allowed to use modifications if they choose. At SCS, a student can use modifications, but the repetitions completed in this manner do not count toward the student's score. The students at SCS had lower scores in the PACER and curl-up in the pre-test and modifications could be a factor. Each school recorded the assessments differently. At WCS, another student judged the student and at SCS, the teacher judged everyone's repetitions. This may mean that the WCS values are less reliable.

There are testing differences in the PACER as well. Starting at the beginning of the intervention year, WCS required students to have both feet over the line as opposed to only one foot touching the line (the rule that WCS used in the past and that SCS uses). This could help explain why the PACER decline was largely significant in the WCS group. Additionally, due to facility size, SCS completes the PACER15 and WCS uses the PACER15. There is a conversion between the two tests, but a student at WCS still runs 5 more meters per lap which is different from SCS and should be considered and standardized in the future.

At WCS, some students did not receive the full dosage of the modified warm-up protocol. As noted earlier, one group at WCS completed their FitnessGram testing earlier in the spring due to spring break. This means that those students only received the protocol for three days as opposed to multiple weeks in the spring before the testing. One class did gymnastics and switched to skipping the cardiovascular programming for two weeks and completing the strength programming on Monday, Wednesday, and Friday due to how the gym was set up. These deviations may have a negative effect on the results.

At both schools, the students were informed of the values they needed to reach to be considered in the "healthy fitness zone" of FitnessGram. This raises questions about the validity because there is a possibility that students may reach this number of repetitions and stop or slow down. It is difficult to measure a true maximum for a fit student if they are aware of an outside goal at which they feel they can stop. Conversely, a less fit individual may benefit from hearing this value and try harder to reach the number. It may be beneficial in a future study to measure each student's engagement in attempt to gauge the effort from each student.

It is important to consider other factors influencing fitness in these students. Not only do the students complete the physical education warm-up, but they participate in the school's physical education curriculum and may or may not participate in physical activity outside of school. Measuring external physical activity of the students was beyond the scope of this study, so it could not be factored into the analysis. This study was also limited because it lacked subject-matched historical data from SCS, so maturation cannot be compared between schools.

Additionally, the dose of the warm-up protocol should be examined. At WCS, the students completed the cardio portion three times per week and the strength portion of the protocol two times per week. In all, the students there completed the full program 2.5 times per week. At SCS, since the students completed the cardio protocol one day per week and the strength protocol one day per week, those students only did the full program one time per week. Future studies should monitor exercise dose. Potentially, the students need more or less of the dose to have favorable effects. In future analyses, it would be beneficial to include a control group using a standardized, basic warm-up as utilized by Richmond et al.

There is an added benefit to the implemented warm-up program that are independent of these four fitness tests. It was observed at WCS that the students previously took a long time to

change clothing and the amount of time on the class activity would be limited. Since the implemented warm-up protocol was completed as a class, the students were pressured to change faster and have more time for class. This means that there is more time for the students to reach the recommended physical activity levels.

Comparing this study to the study by Richmond et al provides insight into the study design. The Richmond et al study used students grades 7-9 in Calgary, Alberta and implemented a neuromuscular program for 12 weeks. The students attended physical education class 2-3 times per week, depending on the school. The intervention group completed a session including aerobic, balance, core, and lower extremity exercises. The specific exercises were chosen because they were able to produce at least 75% of max heart rate, an intensity shown in the literature to increase cardiovascular fitness. The study found a small positive change in aerobic fitness despite the short duration. It is important to note that this study included a control group, while the study at the Vermont schools did not. These are key differences between the two studies, and they may help explain the successes of the Richmond et al study compared to this study in Vermont.

A study by Murray et al noted improvements in fitness-related variables with the implementation of a "FitnessGram Friday."[74] The study found significant improvements in push-up scores, trunk lift scores, mile run times, and number of people in the Healthy Fitness Zone. While these results cannot be directly compared to the results from WCS and SCS, it is important to note that an implementation of a program focusing on aerobic and muscular endurance can improve fitness variables in sixth grade students. Perhaps a more specific intervention in the Vermont middle schools could improve FitnessGram scores in these areas. For example, in this study, students learned and were able to practice how to pace for the mile

test. The students were also provided incentives to participate in FitnessGram Fridays, as they were entered in random drawings for MP3 players if they participated. It would be interesting to examine the role of incentives in improving FitnessGram test results.

In the future, it may be beneficial to prescribe a set heart rate intensity value for the students. Another alteration could be to complete a combination of cardiovascular and strength exercises during each physical education class, something similar to the FitnessGram Friday, as opposed to a dedicated day for each. Further modification of the FIFA 11+ warm-up protocol may create a program beneficial for injury protection as well as fitness variables. Additional comparison between the FIFA 11+ and the FIFA 11+ For Kids may be necessary. FIFA 11+ For Kids is designed for ages between 7 and 13, which is the age group in this study and may be appropriate for a future study. Either way, consideration of class time constraints would be needed. Standardizing who recorded the scores would be necessary as well because there may be effects of a teacher assessing as opposed to another student in the class.

In conclusion, the implemented modified FIFA 11+ warm-up protocol did not appear to have many beneficial effects on fitness variables in students from both Vermont middle schools. In fact, the effects appeared to be detrimental, especially in the PACER cardiovascular assessment. A future controlled study is needed to see if these results remain. The FIFA 11+ program has been shown in literature to be beneficial for injury prevention, but this study did not support that it is beneficial for fitness. Altering the program to have a running component may be a start to help with fitness scores on the FitnessGram tests. Creating a program that can help reduce risk of injury and increase fitness, while promoting physical activity, would be beneficial for both children in sports and for children heading towards obesity.

References

1. American Heart Association. *Physical Education in Public Schools*. 2012.
2. Brock, D.W., et al., *Association Between Insufficiently Physically Active and the Prevalence of Obesity in the United States.* 6, 2009. **1**.
3. Simons-Morton, B.G., et al., *The Physical Activity of Fifth-Grade Students during Physical Education Classes.* American Journal of Public Health, 1993. **83**(2).
4. Yard, E. and D. Comstock, *Injury Patterns by Body Mass Injex in US High School Athletes.* Journal of Physical Activity and Health, 2011. **8**.
5. Mandelbaum, B.R., et al., *Effectiveness of a neuromuscular and proprioceptive training program in preventing anterior cruciate ligament injuries in female athletes: 2-year follow-up.* Am J Sports Med, 2005. **33**(7): p. 1003-10.
6. Thompson-Kolesar, J.A., et al., *Age Influences Biomechanical Changes After Participation in an Anterior Cruciate Ligament Injury Prevention Program.* Am J Sports Med, 2018. **46**(3): p. 598-606.
7. Prodromos, C.C., et al., *A Meta-analysis of the Incidence of Anterior Cruciate Ligament Tears as a Function of Gender, Sport, and a Knee Injury–Reduction Regimen.* Arthroscopy: The Journal of Arthroscopic & Related Surgery, 2007. **23**(12): p. 1320-1325.e6.
8. Hewett, T., et al., *The Effect of Neuromuscular Training on the Incidence of Knee Injury in Female Athletes.* The American Journal of Sports Medicine, 1999. **27**(6).
9. Joseph, A.M., et al., *A multisport epidemiologic comparison of anterior cruciate ligament injuries in high school athletics.* J Athl Train, 2013. **48**(6): p. 810-7.
10. Friel, N.A. and C.R. Chu, *The Role of ACL Injury in the Development of Posttraumatic Knee Osteoarthritis.* Clin Sport Med, 2013.
11. Sommerlath, K., J. Lysholm, and J. Gillquist, *The long-term course after treatment of acute anterior cruciate ligament ruptures: A 9 to 16 year followup.* American Orthopaedic Society for Sports Medicine, 1991. **19**(2).
12. McKay, C.D., et al., *The effect of coach and player injury knowledge, attitudes and beliefs on adherence to the FIFA 11+ programme in female youth soccer.* Br J Sports Med, 2014. **48**(17): p. 1281-6.
13. Soligard, T., et al., *Comprehensive warm-up programme to prevent injuries in young female footballers-cluster randomised controlled trial.* British Medical Journal, 2009. **338**(7686).
14. Silvers-Granelli, H., et al., *Efficacy of the FIFA 11+ Injury Prevention Program in the Collegiate Male Soccer Player.* Am J Sports Med, 2015. **43**(11): p. 2628-37.
15. Owoeye, O.B.A., et al., *Efficacy of the FIFA 11+ Warm-Up Programme in Male Youth Football- A Cluster Randomised Controlled Trial.* Journal of Sports Science and Medicine, 2014. **13**.
16. *FIFA 11+ For Kids Manual: A Warm-Up Programme For Preventing Injuries in Children's Football.*
17. Barber Foss, K.D., G.D. Myer, and T.E. Hewett, *Epidemiology of basketball, soccer, and volleyball injuries in middle-school female athletes.* Phys Sportsmed, 2014. **42**(2): p. 146-53.

18. Ardern, C.L., et al., *2018 International Olympic Committee consensus statement on prevention, diagnosis and managemet of paediatric anterior cruciate ligament (ACL) injuries.* Knee Surgery, Sports Traumatology, Arthroscopy, 2018. **26**.
19. Racette, S.B., et al., *Sex differences in FITNESSGRAM(R) health risk based on aerobic capacity and body composition among urban public elementary school children.* Prev Med, 2017. **103**: p. 56-59.
20. Pate, R.R. and S. Daniels, *Institute of Medicine Report on Fitness Measures and Health Outcomes in Youth.* JAMA Pediatrics, 2013. **167**(3).
21. Plowman, S.A.a.M., Marilu D., *Fitnessgram/Activitygram Reference Guide (4th Edition).* 2013.
22. Laurson, K.R., J.C. Eisenmann, and G.J. Welk, *Body fat percentile curves for U.S. children and adolescents.* Am J Prev Med, 2011. **41**(4 Suppl 2): p. S87-92.
23. Flegal, K.M., et al., *Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010.* JAMA, 2012. **307**(5): p. 491-7.
24. Hales, C.M., et al., *Trends in Obesity and Severe Obesity Prevalence in US Youth and Adults by Sex and Age, 2007-2008 to 2015-2016.* 2018.
25. Wang, Y., et al., *Will all Americans become overweight or obese? estimating the progression and cost of the US obesity epidemic.* Obesity (Silver Spring), 2008. **16**(10): p. 2323-30.
26. Bai, Y. and G.J. Welk, *School and County Correlates Associated with Youth Body Mass Index.* Med Sci Sports Exerc, 2017. **49**(9): p. 1842-1850.
27. Chen, H.L., *The scope and impact of obesity in Vermont — Strategies for change.* Preventive Medicine, 2015. **80**: p. 44-46.
28. Sobol-Goldberg, S., J. Rabinowitz, and R. Gross, *School-based obesity prevention programs: a meta-analysis of randomized controlled trials.* Obesity (Silver Spring), 2013. **21**(12): p. 2422-8.
29. Foss, K.D.B., et al., *A School-Based Neuromuscular Training Program and Sport-Related Injury Incidence: A Prospective Randomized Controlled Clinical Trial.* J Athl Train, 2018. **53**(1): p. 20-28.
30. Brenner, J.S., M. American Academy of Pediatrics Council on Sports, and Fitness, *Overuse injuries, overtraining, and burnout in child and adolescent athletes.* Pediatrics, 2007. **119**(6): p. 1242-5.
31. Sanders, T.L., et al., *Incidence of Anterior Cruciate Ligament Tears and Reconstruction: A 21-Year Population-Based Study.* Am J Sports Med, 2016. **44**(6): p. 1502-7.
32. Amako, M., et al., *Effect of Static Stretching on Prevention of Injuries for Military Recruits.* Military Medicine, 2003. **168**(6).
33. Hartig, D. and J.M. Hendersen, *Increasing Hamstring Flexibility Decreases Lower Extremity Overuse Injuries in Military Basic Trainees.* The American Journal of Sports Medicine, 1999. **27**(2).
34. Verrall, G.M., J.P. Slavotinek, and P.G. Barnes, *The effect of sports specific training on reducing the incidence of hamstring injuries in professional Australian Rules football players.* Br J Sports Med, 2005. **39**(6): p. 363-8.
35. Gilchrist, J., et al., *A randomized controlled trial to prevent noncontact anterior cruciate ligament injury in female collegiate soccer players.* Am J Sports Med, 2008. **36**(8): p. 1476-83.

36. Longo, U.G., et al., *The FIFA 11+ program is effective in preventing injuries in elite male basketball players: a cluster randomized controlled trial.* Am J Sports Med, 2012. **40**(5): p. 996-1005.
37. Woods, K., P. Bishop, and E. Jones, *Warm-up and Stretching in the Prevention of Muscular Injury.* Sports Med, 2007. **37**(12).
38. Thorborg, K., et al., *Effect of specific exercise-based football injury prevention programmes on the overall injury rate in football: a systematic review and meta-analysis of the FIFA 11 and 11+ programmes.* Br J Sports Med, 2017. **51**(7): p. 562-571.
39. Richmond, S.A., et al., *A School-Based Injury Prevention Program to Reduce Sport Injury Risk and Improve Healthy Outcomes in Youth- A Pilot Cluster-Randomized Controlled Trial.* Clin J Sport Med, 2016. **26**(4).
40. Daneshjoo, A., et al., *Effectiveness of injury prevention programs on developing quadriceps and hamstrings strength of young male professional soccer players.* J Hum Kinet, 2013. **39**: p. 115-25.
41. Daneshjoo, A., et al., *Effects of the 11+ and Harmoknee Warm-Up Programs on Physical Performance Measure in Professional Soccer Players.* Journal of Human Kinetics, 2013. **39**.
42. Impellizzeri, F.M., et al., *Physiological and performance responses to the FIFA 11+ (part 2): a randomised controlled trial on the training effects.* J Sports Sci, 2013. **31**(13): p. 1491-502.
43. Nobre, G.G., et al., *Twelve Weeks of Plyometric Training Improves Motor Performance of 7- to 9-Year-Old Boys Who Were Overweight:Obese- A Randomized Controlled Intervention.* Journal of Strength and Conditioning Research, 2016. **31**(8).
44. Daneshjoo, A., et al., *The effects of comprehensive warm-up programs on proprioception, static and dynamic balance on male soccer players.* PLoS One, 2012. **7**(12): p. e51568.
45. Beachy, G. and M. Rauh, *Middle school injuries: a 20-year (1988-2008) multisport evaluation.* J Athl Train, 2014. **49**(4): p. 493-506.
46. Welton, K.L., et al., *Injury Recurrence Among High School Athletes in the United States: A Decade of Patterns and Trends, 2005-2006 Through 2015-2016.* Orthop J Sports Med, 2018. **6**(1): p. 2325967117745788.
47. Nagle, K., et al., *Timing of Lower Extremity Injuries in Competition and Practice in High School Sports.* Sports Health, 2017. **9**(3): p. 238-246.
48. Tirabassi, J., et al., *Epidemiology of High School Sports-Related Injuries Resulting in Medical Disqualification: 2005-2006 Through 2013-2014 Academic Years.* Am J Sports Med, 2016. **44**(11): p. 2925-2932.
49. Roos, K.G., et al., *Epidemiology of Overuse Injuries in Collegiate and High School Athletics in the United States.* Am J Sports Med, 2015. **43**(7): p. 1790-7.
50. Warner, K., et al., *A Comparison of High School Boys' and Girls' Lacrosse Injuries: Academic Years 2008-2009 Through 2015-2016.* J Athl Train, 2018.
51. Lohmander, L.S., et al., *The Long-term Consequences of Anterior Cruciate Ligament and Meniscus Injuries.* The American Journal of Sports Medicine, 2007. **35**(10).
52. Johnson, V.L. and D.J. Hunter, *The epidemiology of osteoarthritis.* Best Practice & Research Clinical Rheumatology, 2014.
53. Roos, E.M., *Joint injury causes knee osteoarthritis in young adults.* Current Opinion in Rheumatology, 2005. **17**.

54. Roos, E.M. and L.S. Lohmander, *The Knee Injury and Osteoarthritis Outcome Score (KOOS)- from joint injury to osteoarthritis.* Health and Quality of Life Outcomes, 2003.
55. Maffulli, N., et al., *Long-term health outcomes of youth sports injuries.* Br J Sports Med, 2010. **44**.
56. Chaudhari, A.M.W., et al., *Knee Kinematics, Cartilage Morphology, and Osteoarthritis after ACL Injury.* Journal of the American College of Sports Medicine, 2008.
57. Andriacchi, T.P., et al., *Rotational Changes at the Knee after ACL Injury Cause Cartilage Thinning.* Clinical Orthopaedics and Related Research, 2006.
58. McHugh, M.P. and C.H. Cosgrave, *To stretch or not to stretch: the role of stretching in injury prevention and performance.* Scand J Med Sci Sports, 2010. **20**(2): p. 169-81.
59. Pope, R.P., et al., *A randomized trial of preexercise stretching for prevention of lower-limb injury.* Medicine & Science in Sports & Exercise, 2000.
60. Lopes, L., et al., *Flexibility is associated with motor competence in schoolchildren.* Scand J Med Sci Sports, 2017. **27**(12): p. 1806-1813.
61. Haroy, J., et al., *Including the Copenhagen Adduction Exercise in the FIFA 11+ Provides Missing Eccentric Hip Adduction Strength Effect in Male Soccer Players: A Randomized Controlled Trial.* Am J Sports Med, 2017. **45**(13): p. 3052-3059.
62. Rössler, R., et al., *A new injury prevention programme for children s football FIFA 11 Kids can improve motor performance a cluster randomised controlled trial.* Journal of Sports Sciences, 2016. **34**(6).
63. Pomares-Noguera, C., et al., *Training Effects of the FIFA 11+ Kids on Physical Performance in Youth Football Players- A Randomized Control Trial.* Frontiers in Pediatrics, 2018.
64. Welk, G.J., *The Intersections of Science and Practice: Examples From FitnessGram(R) Programming.* Res Q Exerc Sport, 2017. **88**(4): p. 391-400.
65. Bai, Y., P.F. Saint-Maurice, and G.J. Welk, *Fitness Trends and Disparities Among School-Aged Children in Georgia, 2011-2014.* Public Health Rep, 2017. **132**(2_suppl): p. 39S-47S.
66. Tomkinson, G.R., et al., *International normative 20 m shuttle run values from 1 142 026 children and youth representing 50 countries.* British Journal of Sports Medicine, 2017. **51**(21): p. 1545-1554.
67. Hartman, J.G. and M. Looney, *Norm-Referenced and Criterion-Referenced Reliability and Validity of the Back-Saver Sit-and-Reach.* Measurement in Physical Education and Exercise Science, 2003. **7**(2).
68. Patterson, P., N. Rethwisch, and D. Wiksten, *Reliability of the Trunk Lift in High School Boys and Girls.* Measurement in Physical Education and Exercise Science, 1997. **1**(1).
69. Patterson, P., et al., *The Validity and Reliability of the Back Saver Sit-and-Reach Test in Middle School Girls and Boys.* Research Quarterly for Exercise and Sport, 1996. **67**(4).
70. Mahar, M.T., et al., *Criterion-Referenced and Norm-Referenced Agreement Between the Mile Run:Walk and PACER.* Measurement in Physical Education and Exercise Science, 1997. **1**(4).
71. Jackson, A.W., et al., *Reliability of The Prudential FITNESSGRAM Trunk Lift Test in Young Adults.* Research Quarterly for Exercise and Sport, 1996. **67**(1).
72. Whittaker, J.L. and C.A. Emery, *Impact of the FIFA 11+ on the structure of select muscles in adolescent female soccer players.* Physical Therapy in Sport, 2015. **16**(3): p. 228-235.

73. Nakase, J., et al., *Whole body muscle activity during the FIFA 11+ program evaluated by positron emission tomography.* PLoS One, 2013. **8**(9): p. e73898.
74. Murray, T.D., et al., *FITNESSGRAM Friday- A Middle School Physical Activity and Fitness Intervention.* International Journal of Exercise Science, 2012. **5**(1).
75. Leger, L.A., et al., *The multistage 20 metre shuttle run test for aerobic fitness.* J Sports Sci, 1988. **6**(2): p. 93-101.

Figure 1. FIFA 11+ protocol.

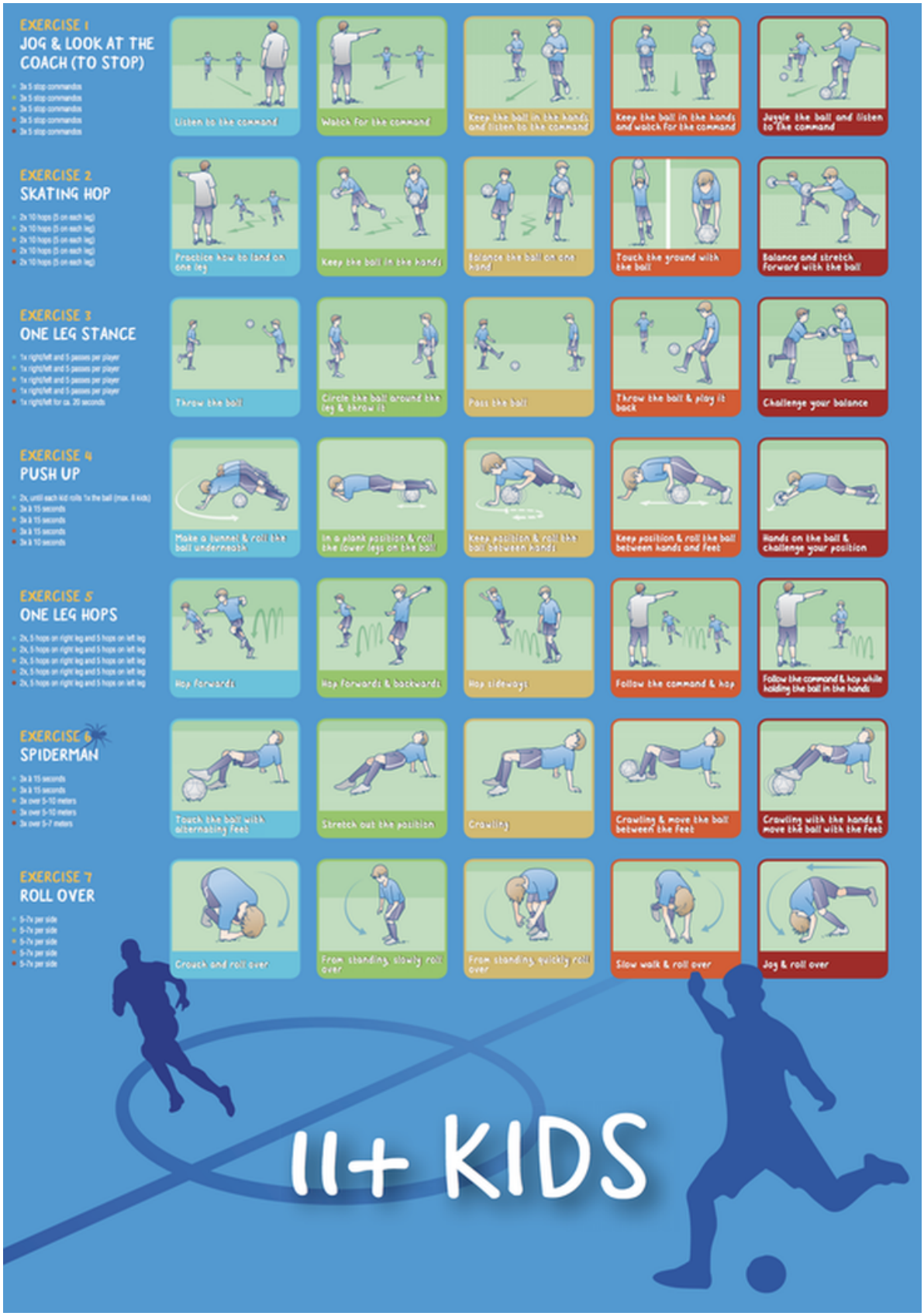

Figure 2. FIFA 11+ For Kids protocol.

Level	Distance	Laps																		
1	15m	1	2	3	4	5	6	7	8	9										
	20m	1	2	2	3	4	5	5	6	7										
2	15m	10	11	12	13	14	15	16	17	18	19									
	20m	8	8	9	10	11	12	12	13	14	15									
3	15m	20	21	22	23	24	25	26	27	28	29	30								
	20m	15	16	17	18	18	19	20	21	22	22	23								
4	15m	31	32	33	34	35	36	37	38	39	40	41	42							
	20m	24	25	25	26	27	28	28	29	30	31	32	32							
5	15m	43	44	45	46	47	48	49	50	51	52	53	54							
	20m	33	34	35	35	36	37	38	38	39	40	41	41							
6	15m	55	56	57	58	59	60	61	62	63	64	65	66	67						
	20m	42	43	44	45	45	46	47	48	48	49	50	51	51						
7	15m	68	69	70	71	72	73	74	75	76	77	78	79	80						
	20m	52	53	54	55	55	56	57	58	58	59	60	61	61						
8	15m	81	82	83	84	85	86	87	88	89	90	91	92	93	94					
	20m	62	63	64	65	65	66	67	68	68	69	70	71	72	72					
9	15m	95	96	97	98	99	100	101	102	103	104	105	106	107	108					
	20m	73	74	75	75	76	77	78	78	79	80	81	82	82	83					
10	15m	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123				
	20m	84	85	85	86	87	88	88	89	90	91	92	92	93	94	94				
11	15m	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138				
	20m	95	96	97	98	98	99	100	101	102	102	103	104	105	105	106				
12	15m	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154			
	20m	107	108	108	109	110	111	112	112	113	114	115	115	116	117	118	118			
13	15m	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171		
	20m	119	120	121	122	122	123	124	125	125	126	127	128	128	129	130	131	131		
14	15m	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188		
	20m	132	133	134	135	135	136	137	138	138	139	140	141	142	142	143	144	144		
15	15m	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205		
	20m	145	146	147	148	148	149	150	151	152	152	153	154	155	155	156	156	157		
16	15m	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	
	20m	158	159	160	161	162	162	163	164	165	165	166	167	168	168	169	170	171	171	
17	15m	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	
	20m	172	173	174	175	175	176	177	178	178	179	180	181	182	182	183	184	185	185	
18	15m	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260
	20m	186	187	187	188	189	190	191	192	192	193	194	195	195	196	197	198	198	199	200
19	15m	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279
	20m	201	201	202	203	204	205	205	206	207	208	208	209	210	211	212	212	213	214	215
20	15m	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298
	20m	216	216	217	218	218	219	220	221	222	222	223	224	225	225	226	227	228	228	229

Figure 3. Conversion chart of PACER15 and PACER20.

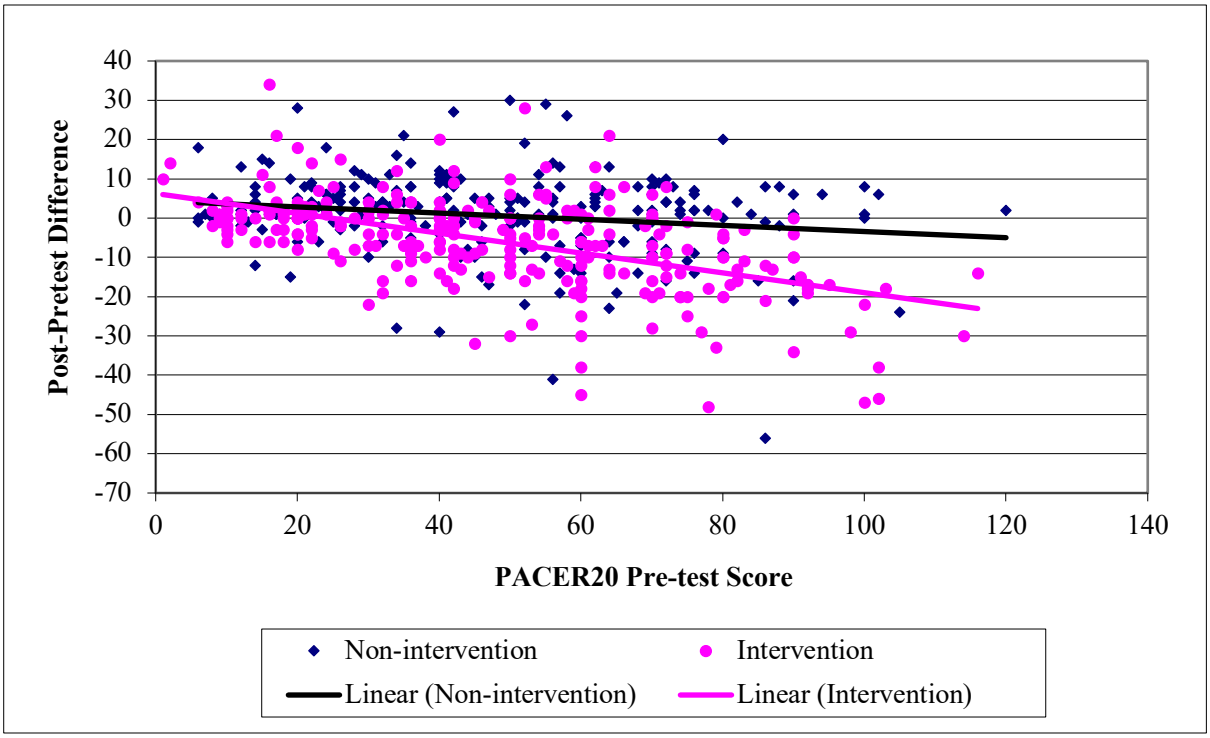

Figure 4. Difference from post- to pre-test compared to the pre-test score in the non-intervention year and intervention year for PACER test at WCS.

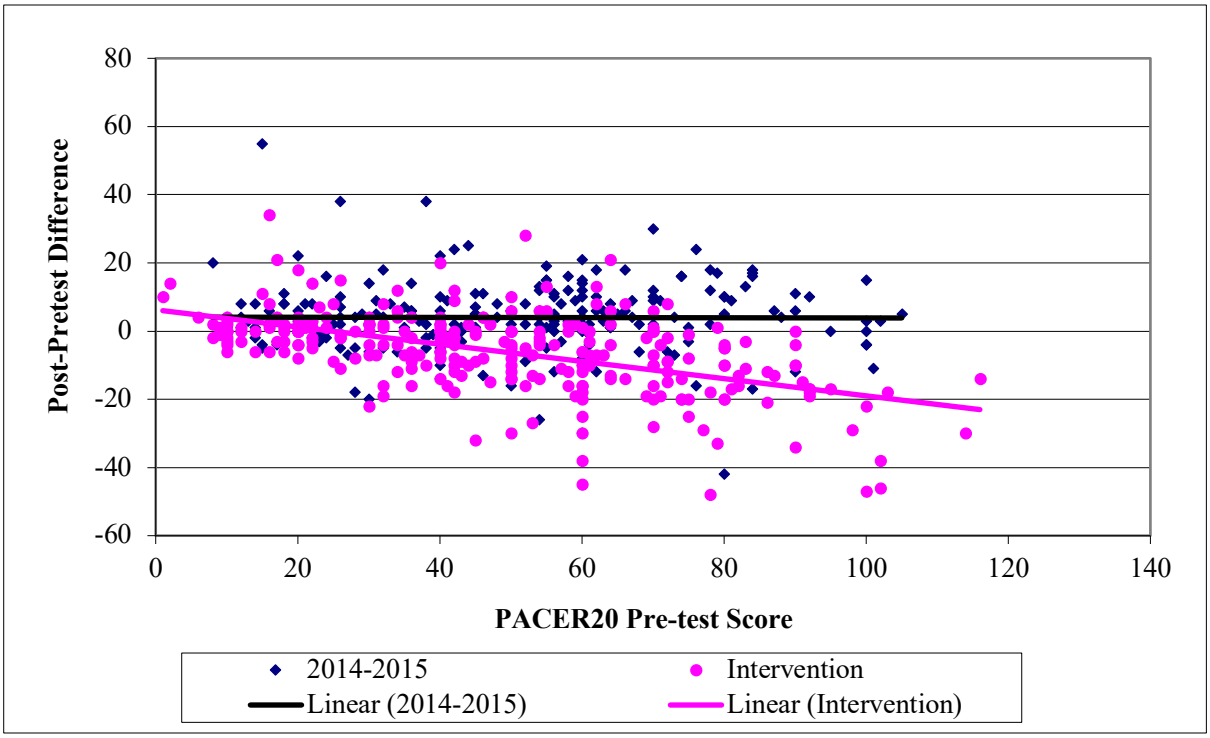

Figure 5. Difference from post- to pre-test compared to the pre-test score in the 2014-2015 year and intervention year for PACER test at WCS.

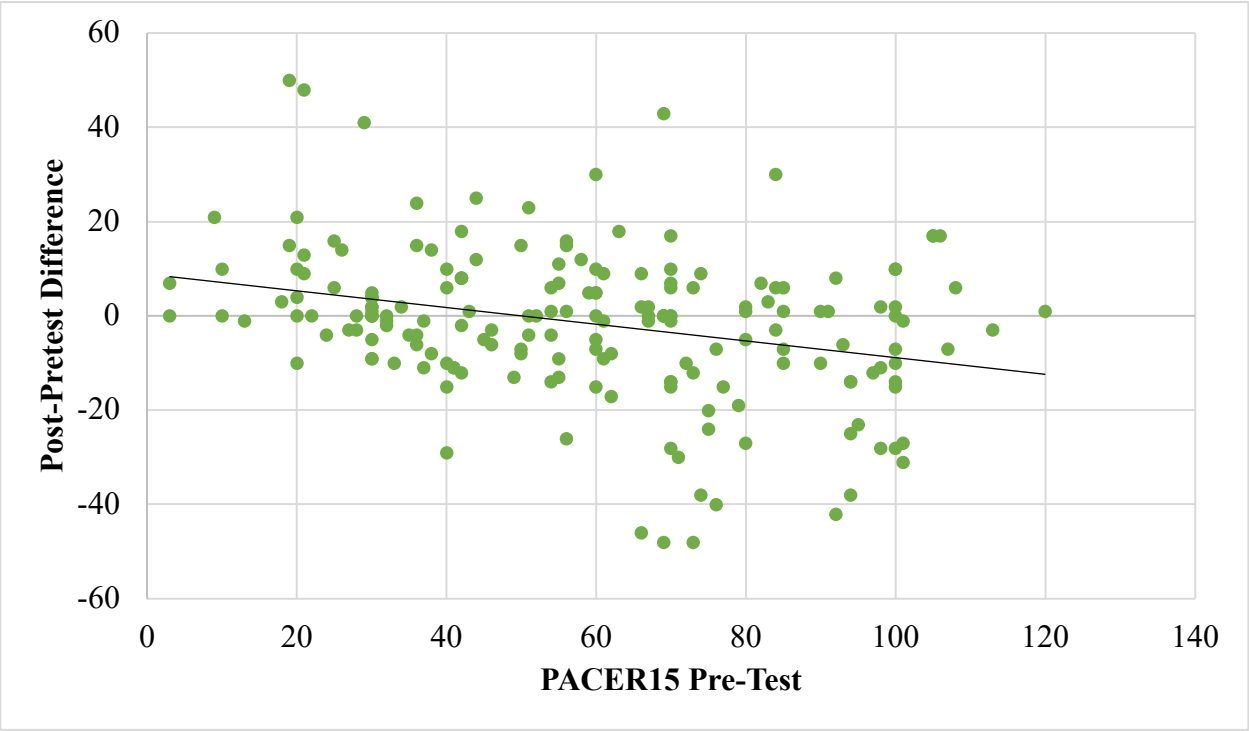

Figure 6. Difference from post- to pre-test for PACER test at SCS in the intervention year.

"UVM FITNESS WARM UP" [2017]

MONDAY + WEDNESDAY + FRIDAY [RUNNING]

(4 lines; 4 cones per line; baseline, foul line, half court, endline)

1	**"STRAIGHT AHEAD"**	(jog forward to endline; jog back)
2	**"HIP OUT"**	(jog forward; right knee 12 to 3 o'clock; jog forward; left knee 12 to 9 o'clock; jog back)
3	**"HIP IN"**	(jog forward right knee 3 to 12 o'clock; jog forward; left knee 9 to 12 o'clock; jog back)
4	**"CIRCLE PARTNER"**	(jog forward to cone; shuffle to meet and circle partner [do-si-do]; shuffle back to cone; jog forward to next cone/line; jog back)
5	**"SHUFFLE JUMP"**	(jog forward; shuffle toward partner sideways; jump; land softly on both feet; shuffle back to cone; jog forward to next cone/line; jog back)
6	**"FORWARD 2 BACK ONE"**	(run forward 2 lines; backwards 1 line; continue until endline; jog back)
7	**"ACROSS THE COURT"**	(run 75-80% forward to endline; jog back)
8	**"BOUNDING"**	(few strides; bound/leap to end line; [alternate R,L,R,L, leap over puddle]; jog back)
9	**"PLANT AND PAUSE"**	(run angle 1,2,3,4 steps; plant outside foot and pause; change direction… run angle 1,2,3,4 plant outside foot and pause; jog back)

Table 1. Modified FIFA 11+ cardiovascular warm-up protocol as it was posted at WCS.

"UVM FITNESS WARM UP" [2017]

TUESDAY + THURSDAY [STRENGTH AND BALANCE]

(scattered on black lines; face the scoreboard wall)

1	**"STATIC BENCH"**	(plank; support body with forearms) **20-30 seconds**
2	**"SIDE BENCH"**	(on side; stack knees; lift top leg; lift hips) **20-30 seconds each leg**
3	**"SINGLE LEG BALANCE"**	(hands on hips; knees slight bend; 1 foot off floor) **20-30 seconds each leg**
4	**"T-BALANCE"**	(stand on one leg; arms forward; focus point on floor) **3-5 reps each leg**
5	**"SQUAT TO TOE RAISE"**	(toes on line; hands on hips; control squat up to toes) **10-15 reps**
6	**"SQUAT JUMPS"**	(hands on hips; squat, upper body forward; jump high; land softly) **10-15 reps**
7	**PUSH UPS**	(straight back; knees down; wall; 8 seconds down) **10-20**

Table 2. Modified FIFA 11+ strength warm-up protocol as it was posted at WCS.

	Non-intervention Year		Intervention Year			Change from non-intervention year		
	Mean	SE	Mean	SE		Difference	SE	p-value
Pre-Test								
PACER20	44.71	1.44	48.60	1.44		3.88	0.69	< 0.001
Aerobic capacity	48.76	0.50	49.09	0.50		0.34	0.25	0.177
Curl-ups	32.56	1.34	38.87	1.34		6.30	0.97	<0.001
Reach	9.50	0.13	10.12	0.13		0.62	0.08	<0.001
Post-Test								
PACER20	45.80	1.33	42.15	1.32		-3.65	0.73	<0.001
Aerobic capacity	48.78	0.47	46.41	0.47		-2.37	0.26	<0.001
Curl-ups	36.37	1.39	41.01	1.39		4.64	0.99	<0.001
Reach	9.58	0.13	10.38	0.13		0.80	0.09	<0.001
Difference (post - pretest)								
PACER20	0.87	0.68	-5.81	0.66		-6.69	0.90	< 0.001
Aerobic capacity	-0.06	0.24	-2.45	0.24		-2.39	0.32	< 0.001
Curl-ups	3.62	0.87	2.07	0.87		-1.55	1.23	0.207
Reach	0.08	0.07	0.27	0.07		0.19	0.09	0.033

Table 3. Test scores and changes from pre to post-test for non-intervention and intervention years in WCS.

Males								
	Non-intervention Year		Intervention Year			Change from non-intervention year		
	Mean	SE	Mean	SE		Difference	SE	p-value
Pre-Test								
PACER20	50.63	2.16	54.60	2.15		3.97	1.11	< 0.001
Aerobic capacity	50.81	0.76	51.21	0.76		0.40	0.39	0.306
Curl-ups	32.13	1.91	40.51	1.91		8.38	1.41	<0.001
Reach	8.47	1.97	9.21	1.97		0.74	0.13	<0.001
Post-Test								
PACER20	51.77	2.00	47.91	2.00		-3.86	1.27	0.003
Aerobic capacity	50.88	0.71	48.41	0.71		-2.47	0.45	<0.001
Curl-ups	37.44	1.94	43.76	1.94		6.32	1.40	<0.001
Reach	8.63	1.93	9.52	1.92		0.89	0.13	<0.001
Difference (post - pretest)								
PACER20	0.57	1.16	-6.02	1.14		-6.59	1.53	< 0.001
Aerobic capacity	-0.15	0.41	-2.57	0.41		-2.43	0.55	< 0.001
Curl-ups	5.12	1.26	2.86	1.26		-2.26	1.79	0.209
Reach	0.16	0.11	0.33	0.11		0.17	0.14	0.246
Females								
	Non-intervention Year		Intervention Year			Change from non-intervention year		
	Mean	SE	Mean	SE		Difference	SE	p-value
Pre-Test								
PACER20	38.76	1.78	42.53	1.77		3.77	0.83	< 0.001
Aerobic capacity	46.69	0.61	46.95	0.61		0.26	0.30	0.393
Curl-ups	33.00	1.87	37.24	1.87		4.25	1.31	0.002
Reach	10.53	1.44	11.02	1.43		0.49	0.10	<0.001
Post-Test								
PACER20	39.87	1.61	36.43	1.60		-3.43	0.75	<0.001
Aerobic capacity	46.70	0.56	44.42	0.56		-2.28	0.26	<0.001
Curl-ups	35.31	1.99	38.29	1.99		2.97	1.39	0.035
Reach	10.51	0.14	11.23	0.14		0.72	0.12	<0.001
Difference (post - pretest)								
PACER20	1.18	0.70	-5.62	0.68		-6.79	0.93	< 0.001
Aerobic capacity	0.04	0.25	-2.33	0.24		-2.36	0.33	< 0.001
Curl-ups	2.14	1.18	1.28	1.18		-0.86	1.67	0.608
Reach	-0.01	0.07	0.21	0.07		0.22	0.10	0.037

Table 4. Test scores and changes from pre to post-test for non-intervention and intervention years by sex at WCS.

	Shelburne		Williston			
	Mean	SE	Mean	SE		p-value
Pre-Test						
PACER20	45.03	1.45	48.60	1.44		0.089
Aerobic capacity	47.63	0.52	49.09	0.50		0.048
Curl-ups	64.37	1.23	38.87	1.34		<0.001
Reach	9.96	0.17	10.12	0.13		0.389
Post-Test						
PACER20	42.82	1.44	42.15	1.32		0.532
Aerobic capacity	46.51	0.52	46.41	0.47		0.679
Curl-ups	64.48	1.33	41.01	1.39		<0.001
Reach	9.86	0.17	10.38	0.13		0.014
Difference (post - pretest)						
PACER20	-1.16	0.87	-5.81*	0.66		< 0.001
Aerobic capacity	-0.83*	0.31	-2.45*	0.24		< 0.001
Curl-ups	0.06	1.28	2.07*	0.87		0.208
Reach	-0.10	0.10	0.27*	0.07		< 0.001

*Significant change (increase or decrease) from pre- to post-test

SUMMARY OF RESULTS

Pre-test: Shelburne pre-tests were a bit lower for PACER20 and aerobic capacity, and much higher for curl-ups.

Post-test: Shelburne post-tests were higher for curl-ups and lower for reach.

Difference: Declines in PACER20 and aerobic capacity were smaller for Shelburne. This was partly due to the inverse relationship between pre-test scores and the size of decline (the larger the pre-test score, the larger the decline) because Shelburne had lower pre-test scores.
Shelburne had a non-significant decline in reach, while Williston had a significant increase, which resulted in a significant difference in the pre to post change between schools.

P-values of differences:
SCS PACER: $p = 0.18$
SCS aerobic capacity: $p = 0.007$
SCS curl-ups: $p = 0.96$
SCS sit-and-reach: $p = 0.31$
WCS PACER, aerobic capacity, sit-and-reach: ($p < 0.001$)
WCS curl-ups: $p = 0.030$

Table 5. Pre-test, post-test and changes from pre- to post-test for SCS and WCS in the intervention year.